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Sughrue
SUGHRUE MION, PLLC

2100 Pennsylvania Avenue, NW
Washington, DC 20037-3213
T 202.293.7060
F 202.293.7860

1010 El Camino Real
Menlo Park, CA 94025-4345
T 650.325.5800
F 650.325.6606

Toei Nishi Shimbashi Bldg. 4F
13-5 Nishi Shimbashi 1-Chome
Minato-Ku, Tokyo 105-0003
Japan
T 03.3503.3760
F 03.3503.3756

www.sughrue.com

David J. Cushing
T 202-663-7925
dcushing@sughrue.com

November 30, 2001

BOX PCT

Commissioner for Patents
Washington, D.C. 20231

PCT/EP00/04803
-filed December 7, 2000

Re: Application of Rainer MARTIN
PROCESS AND DEVICE FOR THE SUPPRESSION OF NOISE AND ECHOES
Assignee: ALCATEL
Our Ref: Q67428

Dear Sir:

The following documents and fees are submitted herewith in connection with the above application for the purpose of entering the National stage under 35 U.S.C. § 371 and in accordance with Chapter II of the Patent Cooperation Treaty:

- ☐ an executed Declaration and Power of Attorney.
- ☑ an English translation of the International Application.
- ☑ 1 sheet of drawings.
- ☐ an English translation of Article 19 claim amendments.
- ☑ an English translation of Article 34 amendments (annexes to the IPER).
- ☐ an executed Assignment and PTO 1595 form.
- ☐ a Form PTO-1449 listing the ISR references, and a complete copy of each reference.
- ☑ a Preliminary Amendment

The Declaration and Power of Attorney, Assignment, Form PTO-1449 listing the International Search Report (ISR) references and a complete copy of each reference will be submitted at a later date.

It is assumed that copies of the International Application, the International Search Report, the International Preliminary Examination Report, and any Articles 19 and 34 amendments as required by § 371(c) will be supplied directly by the International Bureau, but if further copies are needed, the undersigned can easily provide them upon request.

Sughrue
SUGHRUE MION, PLLC

Commissioner for Patents
Washington, D.C. 20231
Attorney Docket Q67428

November 30, 2001

PLEASE SEE THE ATTACHED PRELIMINARY AMENDMENT BEFORE CALCULATING THE FEE. CLAIM CALCULATIONS ARE BASED ON THE ARTICLE 34 AMENDMENTS MADE TO THE CLAIMS

The Government filing fee is calculated as follows:

Total claims	12	-	20	=		x	$18.00	=	$.00
Independent claims	1	-	3	=		x	$84.00	=	$.00
Base Fee									$890.00
TOTAL FEE									$890.00

A check for the statutory filing fee of $890.00 is attached. You are also directed and authorized to charge or credit any difference or overpayment to Deposit Account No. 19-4880. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. §§ 1.16, 1.17 and 1.492 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Priority is claimed from:

Country	Application No	Filing Date
Germany	19925046.4	June 1, 1999

Respectfully submitted,

David J. Cushing
Registration No. 28,703

SUGHRUE MION, PLLC
2100 Pennsylvania Avenue, N.W.
Washington, D.C. 20037-3213
Telephone: (202) 293-7060
Facsimile: (202) 293-7860

Date: November 30, 2001

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Rainer MARTIN

Appln. No.: Not Assigned

Confirmation No.: Not Assigned

Filed: November 30, 2001

PCT/EP00/04803

Attorney Docket Q67428

Group Art Unit: Not Assigned

Examiner: Not Assigned

For: PROCESS AND DEVICE FOR THE SUPPRESSION OF NOISE AND ECHOES

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination, please amend the above-identified application as follows:

IN THE CLAIMS:

Please enter the following amended claims:

7. (Amended) Process according to claim 1, **characterised in that** the signal estimators (S_1, S_2, ..., S_N) are calculated in a transformed domain, for example into a Fourier or discrete cosine transformation domain.

REMARKS

Entry and consideration of this Amendment is respectfully requested.

Respectfully submitted,

David J. Cushing
Registration No. 28,703

SUGHRUE MION, PLLC
2100 Pennsylvania Avenue, N.W.
Washington, D.C. 20037-3213
Telephone: (202) 293-7060
Facsimile: (202) 293-7860

Date: November 30, 2001

Preliminary Amendment
Attorney Docket Q67428

APPENDIX

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

The specification is changed as follows:

IN THE CLAIMS:

The claims are amended as follows:

7. Process according to ~~one of the preceding Claims~~claim 1, **characterised in that** the signal estimators (S_1, S_2, ..., S_N) are calculated in a transformed domain, for example into a Fourier or discrete cosine transformation domain.

1/prts

Process and device for the suppression of noise and echoes

The invention concerns a process for noise and echo suppression in signals, for example video or speech signals. The invention can be used for example in a telephone facility containing a handsfree facility, in a videophone or a medical imaging device. The invention furthermore concerns a device for implementing this process.

During the recording and transmission of video or speech signals, these signals are often distorted by noise and, in the case of transmission over lines, also frequently distorted by (line) echoes. Furthermore, in the case of speech signals and the use of a handsfree facility, acoustic echoes also occur. In order to improve the subjective quality and the audibility of speech or the sharpness and contrast of images, these disturbances can be reduced by background noise reduction and, if necessary, by an echo reduction device, for example an echo compensator or a level balancer.

The background noise reduction is usually carried out by means of a spectral weighting method into a transformed domain, for example according to a Fourier transformation or a discrete cosine transformation. Methods for the improvement of noisy speech signals are described, for example, in Y. Ephraim and D. Malah, 'Speech Enhancement Using a Minimum Mean-Square Error Short-Time Spectral Amplitude Estimator', IEEE Trans. Acoustics, Speech and Signal Processing, Vol. 32, pp. 1109-1121, 1984, and in D. Malah, R.V. Cox and A.J. Accardi, 'Tracking Speech-Presence Uncertainty to Improve Speech Enhancement in Non-Stationary Noise Environments', Proc. IEEE Intl. Conf. Acoustics, Speech, Signal Processing (ICASSP), 1999. Similar methods for the reduction of noise in image signals are known; see, for example, J.S. Lim, 'Image Restoration

by Short Space Spectral Subtraction', IEEE Trans. Acoustic, Speech and Signal Proc., Vol. 28, pp 191-197, 1980 or T. Aach and D. Kunz, Spectral Estimation Filters for Noise Reduction in X-ray Fluoroscopy Imaging', Proc. EUSIPCO, pp. 571-574, 1996.

The reduction of acoustic echoes or line echoes is mainly carried out with an echo compensator, a level balancer, a centre clipper or any combinations of this method. An overview of the prior art relating to speech signals is given, for example, in E. Hänsler, 'The Hands-Free Telephone Problem - An Annotated Bibliography', Signal Processing, Vol. 27, pp. 259-271, 1992, and in E. Hänsler, 'The Hands-Free Telephone Problem - An Annotated Bibliography Update', Annales des Télecommunication, Vol. 49, No. 7-8, pp. 360-367, 1994.

Methods which reduce noise and echoes together have also been known for some time. Earlier methods of this type consist of a simple series circuit of a background noise reduction device and an echo compensator, as described, for example, in U.S. Patent 5,680,393 (Bourmeyster et al.). Improved methods combine the background noise and echo reduction in the context of a true synergy. Here a single filter is used for simultaneous reduction of background noise and the residual echoes remaining after echo compensation. Increased echo attenuation and a complexity advantage is achieved as a result. Such a method is described, for example, in S. Gustafsson et al.: Combined Acoustic Echo Control and Noise Reduction for Hands-free Telephony, Signal Processing, vol. 64, pp. 21-32, 1998. These methods generally consist of the combination of an echo compensator with a filter reducing the residual echoes and the noise.

The disadvantage of the previously known methods is that the methods for common noise and residual echo suppression

use only one single filter suppressing the residual echoes and the noise. Such a method is therefore inadequate when used for changing requirements and varying signal characteristics. For example, different operating conditions are possible during the use of a hands-free facility, depending on whether only the local subscriber is speaking or only the remote subscriber is speaking, or both subscribers are speaking. Since in these operating conditions the requirements of the echo attenuation, for example, are different, it appears to be useful to use different filters adapted to the operating conditions and to change these over according to the operating condition or to use them in a suitably weighted sum. Distortion of the useful signal (for example speech) can therefore be reduced, or even the quality of the remaining background noise improved. In image processing, improvements are thus possible with regard to disturbing block effects, loss of contrast or even the effects of unnatural background patterns ('gratings').

The object of the invention is therefore to specify a process and a device that facilitates effective noise and/or echo reduction, and in so doing causes only minimal distortion in the useful signal and leads to high quality in the residual interference signal, where different signal filters are used in a weighted sum.

This object is achieved by a process that has the features of Claim 1.

The process is based on the fact that the distorted signal does not contain the useful signal, noise and any echo signals at all points in time or in all picture elements or image regions and therefore the use of different signal estimators or signal filters at different instants or for different picture elements is an advantage. For example, the useful signal is then contained only in the distorted

signal when video information or speech is actually being transmitted. Similarly, the occurrence of echoes depends on the activity of the signal sources generating the echo.

According to the invention, different signal estimators or signal filters are now used for the various cases, for example, 'video or speech information present in the signal', 'noise present in the signal',' echoes present in the signal', and any combination of these and according to the level of the signals relative to each other - any linear or nonlinear combinations of these signal estimators or signal filters also being possible. The useful signal is extracted in this way from the distorted signal by one of the estimators or filters adapted to the respective situation. The changing-over of these estimators or filters or their relative weighting in a combination is determined with the aid of variables which are determined from the distorted signal or from other signal sources.

Fig. 1 shows the principal arrangement. z(k) denotes a speech or video signal and $\hat{s}(k)$ the signal free of noise interference or echoes, x(k) denotes any existing external control signal. The distorted signal z(k) is now fed to N signal estimators or signal filters S_1, S_2, ..., S_N. A combination unit K which processes the input signal z(k) and any existing external control signal x(k), controls the selection and/or the combination of the signals delivered by the signal estimators or signal filters S_1, S_2, ..., S_N and forms the noise-free and echo-free signal $\hat{s}(k)$.

Special statistical methods are suitable for determining the estimators and the relative weighting of these estimators to each other. In particular, the selection of one or more suitable signal estimators or signal filters at a specific instant or in a specific picture element can be controlled from the estimated probabilities of the presence of the useful signal, noise or echo signal component in the

distorted signal. An exemplary embodiment of such an estimation method for use in a hands-free facility is specified below.

Fig. 2 shows the combination comprising an echo compensator and an adaptive post filter. The post filter is employed in the frequency domain, using a discrete Fourier transformation (DFT), a spectral weighting and an 'overlap/add' signal synthesis. The post filter is comprised of two part filters and an adaptive combination unit, as shown below.

We consider the sampled and band-limited signals $x(i)$, $y(i)$, $z(i)$ and $\hat{s}(i)$, where i denotes the discrete time index. $x(i)$ is the signal of the remote speaker and $y(i)$ the microphone signal which is comprised of a speech signal $s(i)$, a noise signal $n(i)$ and an echo signal $e(i)$, $y(i) = s(i) + n(i) + e(i)$. The echo-compensated signal $z(i)$ is the microphone signal minus the echo $\hat{e}(i)$, $z(i) = y(i) - \hat{e}(i) = s(i) + n(i) + \bar{e}(i)$ estimated by the compensator. $\bar{e}(i)$ denotes the residual echo after compensation. We further assume that the signals $s(i)$, $x(i)$ and $n(i)$ are statistically independent. The compensated signal $z(i)$ distorted by noise and residual echoes is transformed into the frequency domain by the use of a window function $h(i)$, by assembling a frame of L successive samples of $z(i)$, weighting this frame with the window function and calculating a DFT of length L. The window is displaced by R samples on the input signal prior to the next DFT calculation. The DFT analysis with a sliding window results in a quantity of frequency domain signals which can also be specified with

$$Z(\lambda, k) = \sum_{\mu=0}^{L-1} z(\lambda R - \mu) h(\mu) e^{-j2\pi k\mu/L} \qquad (1)$$

where λ specifies an under-sampled time domain index, $\lambda \varepsilon Z$, and k a frequency index, $k \varepsilon \{0,1..., L-1\}$, and the latter stands in relationship to the standardised centre frequency of the DFT bands, where Ω_k by $\Omega k = k2\Pi/L$. Typically, a sampling rate of f_A = 8000 Hz and a DFT length of L = 2R = 256 is used.

Likewise, the Fourier coefficients of all other signals of the kth frequency index are specified by

- $S_k = A_k\exp(j\alpha_k)$ (undistorted local speech),
- $Y_k = R_k\exp(j'_k)$ (distorted local speech),
- $X_k = B_k\exp(j\beta_k)$ (remote speech),
- $Z_k = D_k\exp(j\varsigma_k)$ (compensated signal)
- $\hat{S}_k = \hat{A}_k\exp(j\alpha_k)$ (interference-suppressed signal)

where the time index λ has been suppressed for the sake of clarity.

The distribution density functions of the local and remote speech can be specified by $p_s(A_k, \alpha_k)$ and $p_x(B_k, \beta_k)$, respectively:

$$p_s(A_k,\alpha_k) = P(H^1_{sk})p_s(A_k,\alpha_k|H^1_s) + P(H^0_{sk})\delta(A_k,\alpha_k) \qquad (2)$$
$$p_x(B_k,\beta_k) = P(H^1_{xk})p_x(B_k,\beta_k|H^1_x) + P(H^0_{xk})\delta(B_k,\beta_k) \qquad (3)$$

where $P(H^1_{sk})$ and $P(H^1_{xk})$ stand for the probabilities that local or remote speech is present and $P(H^0_{sk}) = 1 - P(H^1_{sk}))$ and $P(H^0_{xk}) = 1 - P(H^1_{xk})$ applies. $\delta(.)$ denotes the Dirac function.

The cost function

$$
\begin{aligned}
\mathfrak{C} = \int_{\Omega_Z} &\{P(H_s^0)P(H_x^0)\widehat{A}^2 p(Z|H_s^0, H_x^0) \\
&+ P(H_s^1)P(H_x^1) \iiiint (\widehat{A} - A)^2 p(Z|A, \alpha, B, \beta) \\
&\cdot p_s(A, \alpha|H_s^1) p_x(B, \beta|H_x^1) dA d\alpha dB d\beta \\
&+ P(H_s^0)P(H_x^1)\widehat{A}^2 p(Z|H_s^o, H_x^1) \\
&+ P(H_s^1)P(H_x^0) \iint (\widehat{A} - A)^2 \\
&\cdot p(Z|A, \alpha, H_x^o) p_s(A, \alpha|H_s^1) dA d\alpha\} dZ
\end{aligned}
\tag{4}
$$

is now minimised, where Â denotes the spectral amplitudes of the estimated local signal, which in turn are a function of Z. The solution is given by

$$
\begin{aligned}
\widehat{A} = &\frac{P(H_s^1)P(H_x^1)p(Z|H_s^1, H_x^1)}{P_\Sigma} S_1 \\
&+ \frac{P(H_s^1)P(H_x^0)p(Z|H_s^1, H_x^0)}{P_\Sigma} S_2
\end{aligned}
\tag{5}
$$

where

$$S_1 = E\{A|Z, H_s^1, H_x^1\} \tag{6}$$

$$S_2 = E\{A|Z, H_s^1, H_x^o\} \tag{7}$$

$$
\begin{aligned}
P_\Sigma = &P(H_s^0)P(H_x^0)p(Z|H_s^0, H_x^0) \\
&+ P(H_s^1)P(H_x^1)p(Z|H_s^1, H_x^1) \\
&+ P(H_s^0)P(H_x^1)p(Z|H_s^o, H_x^1) \\
&+ P(H_s^1)P(H_x^0)p(Z|H_s^1, H_x^0)
\end{aligned}
\tag{8}
$$

and

$$p(Z|H_s^0, H_x^0) = \frac{1}{\pi \mathbf{P}_n} \exp(-\gamma_n) \tag{9}$$

$$p(Z|H_s^1, H_x^0) = \frac{1}{\pi \mathbf{P}_n(1+\xi_n)} \exp(-\gamma_n \frac{1}{1+\xi_n}) \tag{10}$$

$$p(Z|H_s^o, H_x^1) = \frac{1}{\pi \mathbf{P}_d} \exp(-\gamma_d) \tag{11}$$

$$p(Z|H_s^1, H_x^1) = \frac{1}{\pi \mathbf{P}_d(1+\xi_d)} \exp(-\gamma_d \frac{1}{1+\xi_d}) \tag{12}$$

E{.} denotes the expected value and E{.|.} a conditional expected value. The conditional expected value is the best estimated value in the context of the mean square error.

P_n, P_d, γ_n, γ_d, ξ_n, and ξ_d are the power density spectra of the interference, the respective *a posteriori* SNR, and the *a priori* SNR for the case where only the local speaker is active (index n) or both speakers are active (index d). In this case the interference-suppressed signal is therefore formed from a linear combination of two signal estimators S_1 and S_2, the estimator S_1 being predominantly used when the local and remote speakers are active, and the estimator S_2 being predominantly used when only the local speaker is active. The process described here, using several signal estimators, distinguishes itself from the prior art in that it produces only very small distortions in the useful signal, with completely naturally-sounding residual background noise.

Claims

1. Process for the reduction of noise and echoes in a useful signal (z(k))

characterised in that

the useful signal (z(k)) affected by noise and echoes is fed to several signal estimators (S_1, S_2, ..., S_N), that are optimised for different signals, namely for the useful signal or noise or echoes, or different signal combinations, namely for a combination comprising useful signal and noise and echoes, or for a combination comprising useful signal and noise, or for a combination comprising echo and noise, and that the output signals of the signal estimators (S_1, S_2, ..., S_N) are combined in a combination unit (K) in relation to the probability relationships of the useful signal, of the noise and of the echo in the useful signal (z(k)) affected by the noise and echoes, determined according to

$$A = \frac{P(H_s^1)P(H_x^1)p(Z|H_s^1,H_x^1)}{P_\Sigma} S_1 + \frac{P(H_s^1)P(H_x^0)p(Z|H_s^1,H_x^0)}{P_\Sigma} S_2$$

so that a noise-reduced and echo-reduced output signal (s(k)) is delivered by the combination unit (K).

2. Process according to Claim 1, **characterised in that** the useful signal (z(k)) affected by noise and echoes is a speech signal affected by noise and echoes.

3. Process according to Claim 1, **characterised in that** the useful signal (z(k)) affected by noise and echoes is a video signal affected by noise and echoes.

4. Process according to Claim 1, **characterised in that** the echoes are acoustic echoes.

5. Process according to Claim 1, **characterised in that** the echoes are line echoes.

6. Process according to Claim 1, **characterised in that** the echoes are reduced by an echo compensator (C) and the residual echoes and the noise are reduced by downstream signal estimators (S_1, S_2, ..., S_N).

7. Process according to one of the preceding Claims, **characterised in that** the signal estimators (S_1, S_2, ..., S_N) are calculated in a transformed domain, for example into a Fourier or discrete cosine transformation domain.

8. Process according to Claim 1, **characterised in that** the signal estimators (S_1, S_2, ..., S_N) are calculated according to the principle of least error squares.

9. Process according to Claim 1, **characterised in that** only the amplitudes of the signals in the transformed domain are taken into account by the signal estimators (S_1, S_2, ..., S_N).

10. Process according to Claim 1, **characterised in that** a cost function is minimised by the signal estimators (S_1, S_2, ..., S_N) jointly.

11. Process according to Claim 1, **characterised in that** the output signals of the signal estimators (S_1, S_2, ..., S_N) are weighted and averaged and the weights are calculated from the probabilities of the presence of the useful signal or of the noise or of the echoes or from the combinations comprising useful signal, noise and echoes.

12. Process according to Claim 1, **characterised in that** acoustic echoes and noise are simultaneously suppressed and the combination comprising the output signals of the signal estimators (S_1, S_2, ..., S_N) is dependent upon the activity of the local and of the remote speaker of a handsfree facility, and the combination unit (K) is additionally controlled via a control signal ($x(k)$) that is dependent upon the remote speaker.

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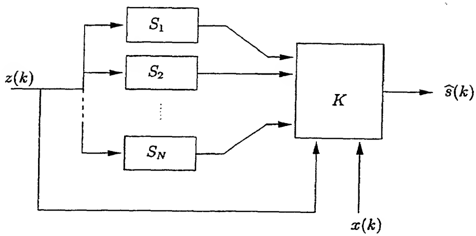

Fig. 1: Device for the reduction of noise and echo interference by means of N signal estimators or signal filters and a combination unit K.

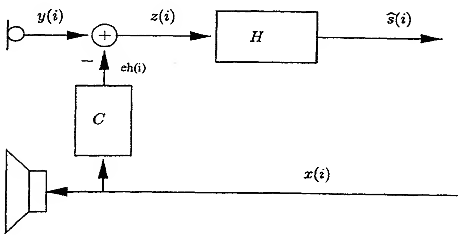

Fig. 2: Device for the joint reduction of acoustic echoes and noise.

M 755

SOLE/JOINT

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, mailing address and citizenship are as stated below next to my name: that I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter claimed and for which a patent is sought in the application entitled: "Process and device for the suppression of noise and echoes"

which application is:

☐ the attached application
(for original application)

☑ Application No. 09980020
(Confirmation No. 2987) filed
, and amended on
(for declaration not accompanying application)

that I have reviewed and understand the contents of the specification of the above-identified application, including the claims, as amended by any amendment referred to above; that I acknowledge my duty to disclose information of which I am aware and which is material to the patentability of this application as defined in 37 C.F.R. 1.56, that I hereby claim priority benefits under Title 35, United States Code §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, §119(e) of any United States provisional application(s), or §365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or of any PCT International application having a filing date before that of the application on which priority is claimed:

Application Number	Country	Filing Date	Priority Claimed Yes	Priority Claimed No
199 25 046.4	DE	June 01, 1999	X	☐

I hereby claim the benefit under 35 United States Code §120 of any United States application(s), or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in a listed prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge my duty to disclose any information material to the patentability of this application as defined in 37 C.F.R. 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application No.	Filing Date	Status

I hereby appoint John H. Mion, Reg. No. 18,879; Thomas J. Macpeak, Reg. No. 19,292; Robert J. Seas, Jr., Reg. No. 21,092; Darryl Mexic, Reg. No. 23,063; Robert V. Sloan, Reg. No. 22,775; Peter D. Olexy, Reg. No. 24,513; J. Frank Osha, Reg. No. 24,625; Waddell A. Biggart, Reg. No. 24,861; Louis Gubinsky, Reg. No. 24,835; Neil B. Siegel, Reg. No. 25,200; David J. Cushing, Reg. No. 28,703; John R. Inge, Reg. No. 26,916; Joseph J. Ruch, Jr., Reg. No. 26,577; Sheldon I. Landsman, Reg. No. 25,430; Richard C. Turner, Reg. No. 29,710; Howard L. Bernstein, Reg. No. 25,665; Alan J. Kasper, Reg. No. 25,426; Kenneth J. Burchfiel, Reg. No. 31,333; Gordon Kit, Reg. No. 30,764; Susan J. Mack, Reg. No. 30,951; Frank L. Bernstein, Reg. No. 31,484; Mark Boland, Reg. No. 32,197; William H. Mandir, Reg. No. 32,156; Brian W. Hannon, Reg. No. 32,778; Abraham J. Rosner, Reg. No. 33,276; Bruce E. Kramer, Reg. No. 33,725; Paul F. Neils, Reg. No. 33,102; Brett S. Sylvester, Reg. No. 32,765; Robert M. Masters, Reg. No. 35,603, George F. Lehnigk, Reg. No. 36,359, John T. Callahan, Reg. No. 32,607, Steven M. Gruskin, Reg. No. 36,818, Peter A. McKenna, Reg. No. 38,551 and Edward F. Kenehan, Reg. No. 28,962, my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and request that all correspondence about the application be addressed to **SUGHRUE, MION, ZINN, MACPEAK & SEAS, PLLC**, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037-3213.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date Dec 3, 2001 First Inventor Rainer MARTIN
First Name Middle Initial Last Name

Residence 52072 Aachen Germany DEX Signature Rainer Martin
City State/Country

Mailing Address: Pfalzgrafenstraße 71
D-52072 Aachen, Germany

Citizenship German